US009454595B2

(12) **United States Patent**
Seo et al.

(10) **Patent No.: US 9,454,595 B2**
(45) **Date of Patent: Sep. 27, 2016**

(54) **DATA ANALYSIS APPARATUS AND METHOD**

(71) Applicant: **SAMSUNG SDS CO., LTD.**, Seoul (KR)

(72) Inventors: **Bum Joon Seo**, Seoul (KR); **Hyung Chan Kim**, Seoul (KR); **Kyu Sam Oh**, Seoul (KR); **Soon Hwan Kwon**, Seoul (KR); **Min Hwan Oh**, Seoul (KR)

(73) Assignee: **SAMSUNG SDS CO., LTD.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 251 days.

(21) Appl. No.: **14/291,855**

(22) Filed: **May 30, 2014**

(65) **Prior Publication Data**

US 2014/0358924 A1 Dec. 4, 2014

(30) **Foreign Application Priority Data**

May 31, 2013 (KR) 10-2013-0062415

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30598*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,081,095 B2 * 7/2006 Lynn A61B 5/412 128/203.23
7,224,642 B1 * 5/2007 Tran G01V 1/003 367/77
7,758,503 B2 * 7/2010 Lynn A61B 5/00 600/300
8,798,840 B2 * 8/2014 Fong G05D 1/0274 700/258
2002/0099702 A1 7/2002 Oddo
2010/0026686 A1 * 2/2010 Koo H04L 41/12 345/440
2012/0057852 A1 * 3/2012 Devleeschouwer G11B 27/034 386/278
2012/0296906 A1 11/2012 Tsai et al.
2013/0060110 A1 * 3/2013 Lynn A61B 7/003 600/324
2014/0043470 A1 * 2/2014 Winterot G02B 9/34 348/135

FOREIGN PATENT DOCUMENTS

KR 2001-0031345 A 4/2001

OTHER PUBLICATIONS

Communication dated Apr. 15, 2015 issued by the Korean Intellectual Property Office in counterpart Korean Patent Application No. 10-2013-0062415.

* cited by examiner

Primary Examiner — Hung Le
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

The present invention relates to a heterogeneous data cluster generation apparatus and method and a data clustering method and apparatus, and more particularly, to a data clustering method and apparatus which cluster data measured by different sensors into a number of groups. Aspects of the present invention provide an apparatus and method for generating clusters by putting together heterogeneous data which are values measured by different types of sensors. Aspects of the present invention also provide an apparatus and method for generating clusters by setting indices in order to effectively cluster multi-dimensional data, massive data, or scattered data.

14 Claims, 7 Drawing Sheets

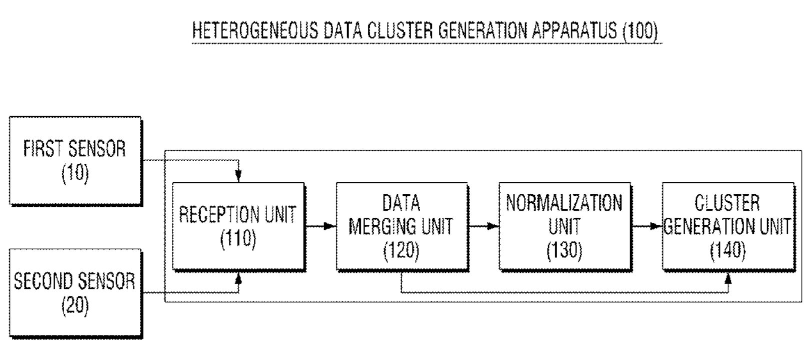


FIG 1

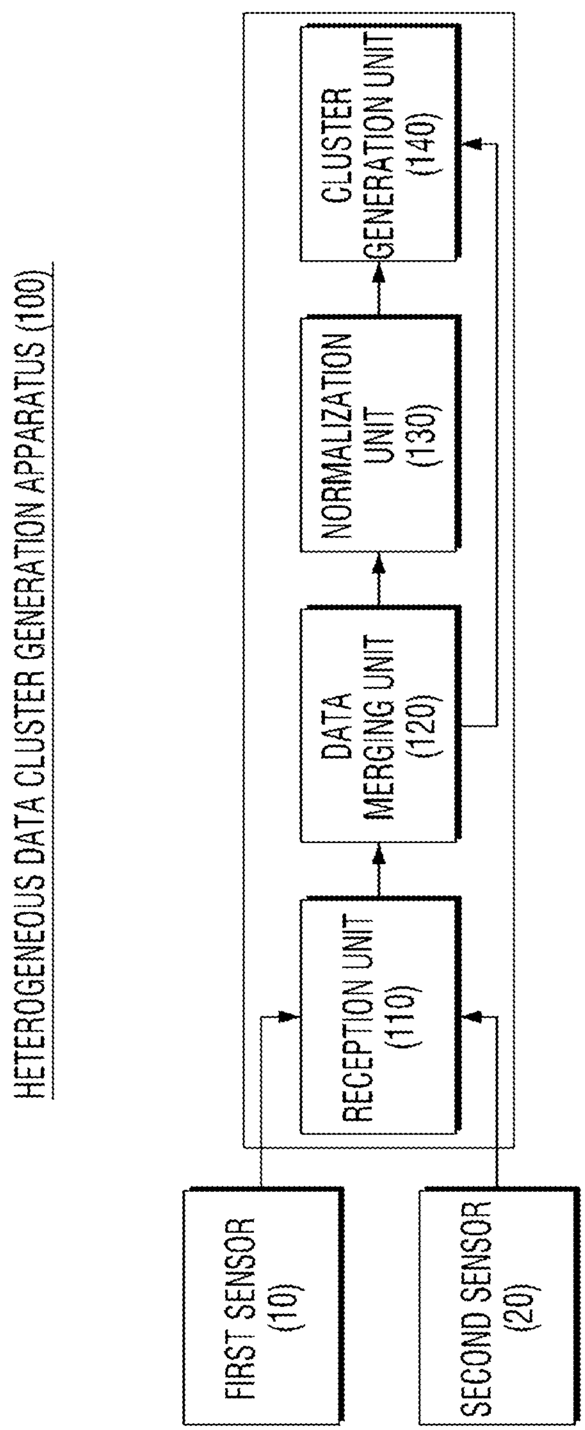

HETEROGENEOUS DATA CLUSTER GENERATION APPARATUS (100)
FIRST SENSOR (10)
SECOND SENSOR (20)
RECEPTION UNIT (110)
DATA MERGING UNIT (120)
NORMALIZATION UNIT (130)
CLUSTER GENERATION UNIT (140)

FIG 2

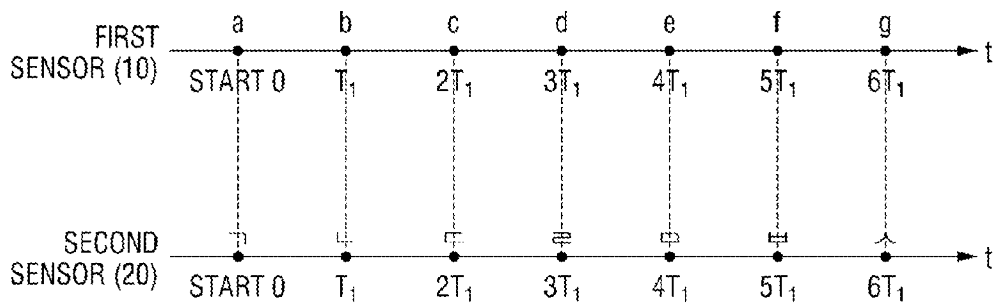

FIRST SENSOR (10)
a b c d e f g
t
START 0 T1 2T1 3T1 4T1 5T1 6T1
SECOND SENSOR (20)
ㄱ ㄴ ㄷ ㄹ ㅁ ㅂ ㅅ
t
START 0 T1 2T1 3T1 4T1 5T1 6T1

FIG 3

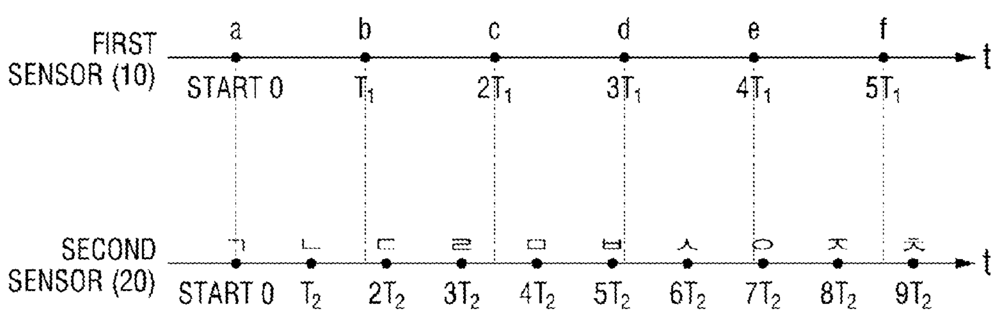
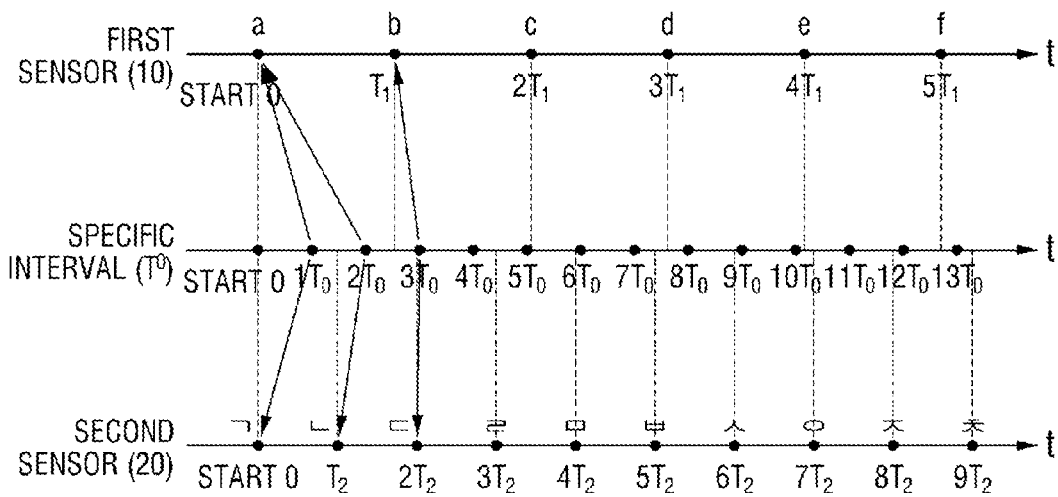
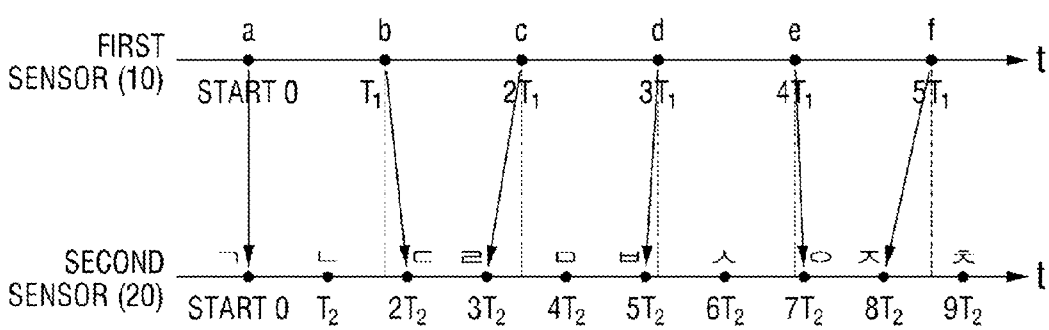

FIRST SENSOR (10)
a b c d e f
t
START 0 T1 2T1 3T1 4T1 5T1
SECOND SENSOR (20)
ㄱ ㄴ ㄷ ㄹ ㅁ ㅂ ㅅ ㅇ ㅈ ㅊ
t
START 0 T2 2T2 3T2 4T2 5T2 6T2 7T2 8T2 9T2

FIG 4



FIRST SENSOR (10)
a
b
c
d
e
f
t
START 0
T_1
$2T_1$
$3T_1$
$4T_1$
$5T_1$
SPECIFIC INTERVAL (T^0)
START 0
$1T_0$ $2T_0$ $3T_0$ $4T_0$ $5T_0$ $6T_0$ $7T_0$ $8T_0$ $9T_0$ $10T_0$ $11T_0$ $12T_0$ $13T_0$
SECOND SENSOR (20)
ㄱ ㄴ ㄷ ㄹ ㅁ ㅂ ㅅ ㅇ ㅈ ㅊ
START 0
T_2 $2T_2$ $3T_2$ $4T_2$ $5T_2$ $6T_2$ $7T_2$ $8T_2$ $9T_2$

FIG 5



FIRST SENSOR (10)
a
b
c
d
e
f
t
START 0
T_1 $2T_1$ $3T_1$ $4T_1$ $5T_1$
SECOND SENSOR (20)
ㄱ ㄴ ㄷ ㄹ ㅁ ㅂ ㅅ ㅇ ㅈ ㅊ
START 0
T_2 $2T_2$ $3T_2$ $4T_2$ $5T_2$ $6T_2$ $7T_2$ $8T_2$ $9T_2$

FIG 6

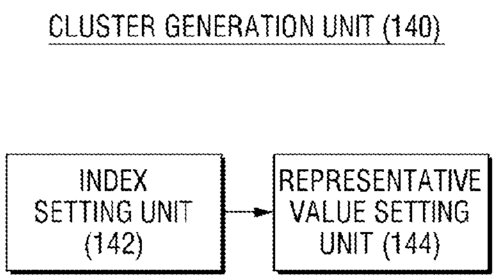

CLUSTER GENERATION UNIT (140)
INDEX SETTING UNIT (142)
REPRESENTATIVE VALUE SETTING UNIT (144)

FIG 7

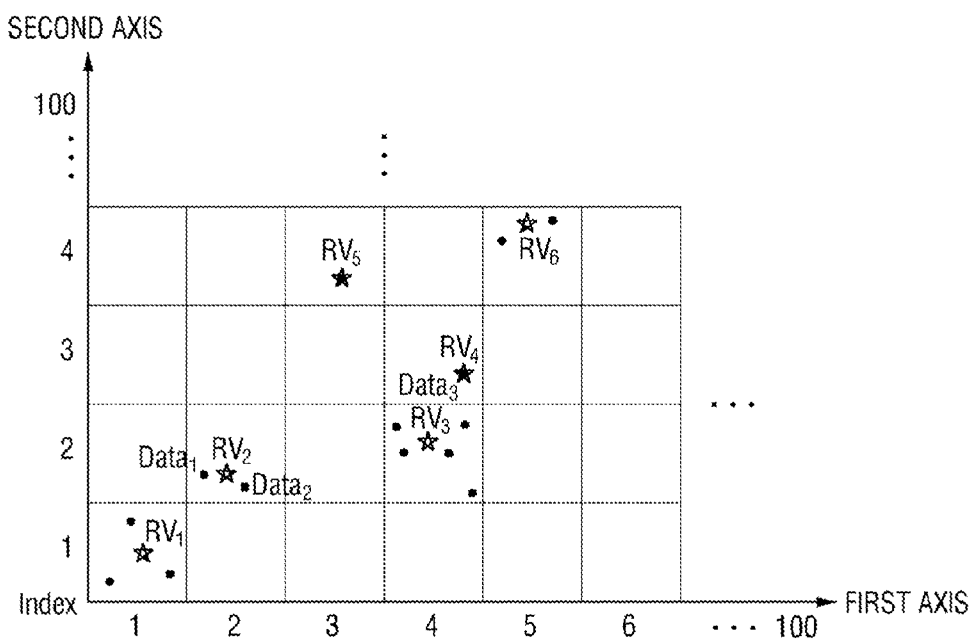

SECOND AXIS
100
4
3
2
1
Index
1
2
3
4
5
6
100
FIRST AXIS
RV1
RV2
RV3
RV4
RV5
RV6
Data1
Data2
Data3

FIG 8

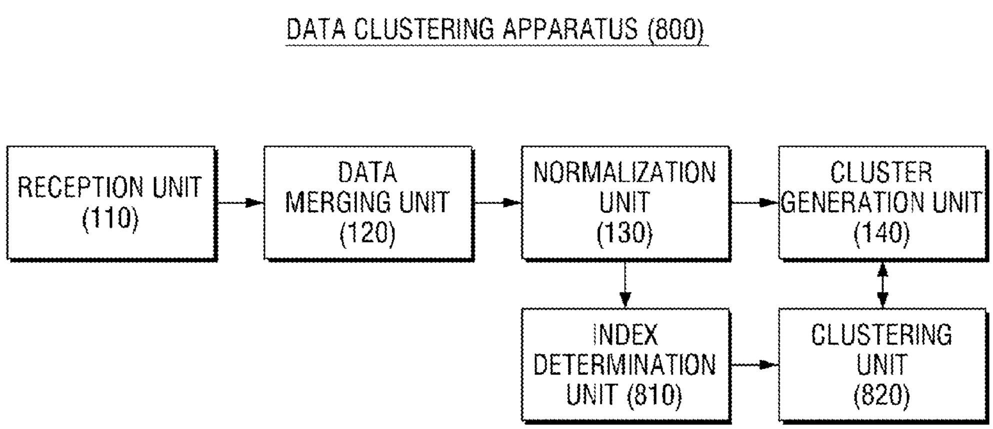

DATA CLUSTERING APPARATUS (800)
RECEPTION UNIT (110)
DATA MERGING UNIT (120)
NORMALIZATION UNIT (130)
CLUSTER GENERATION UNIT (140)
INDEX DETERMINATION UNIT (810)
CLUSTERING UNIT (820)

FIG 9

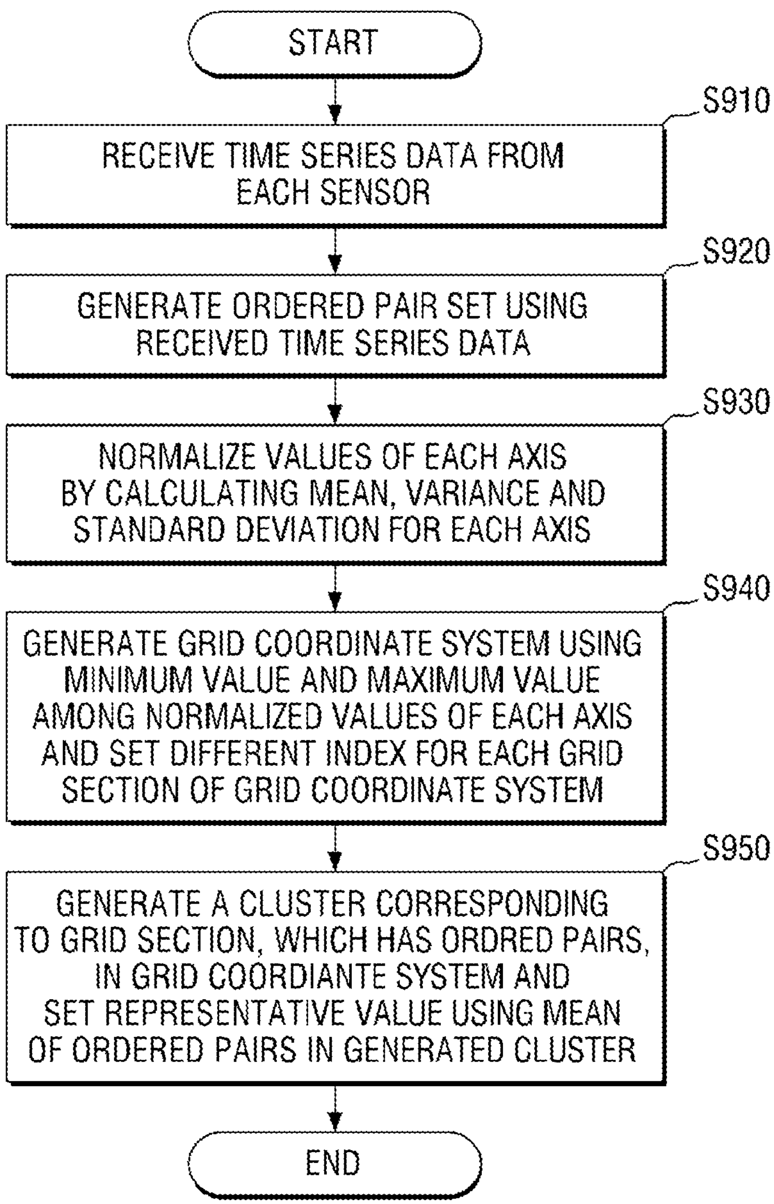
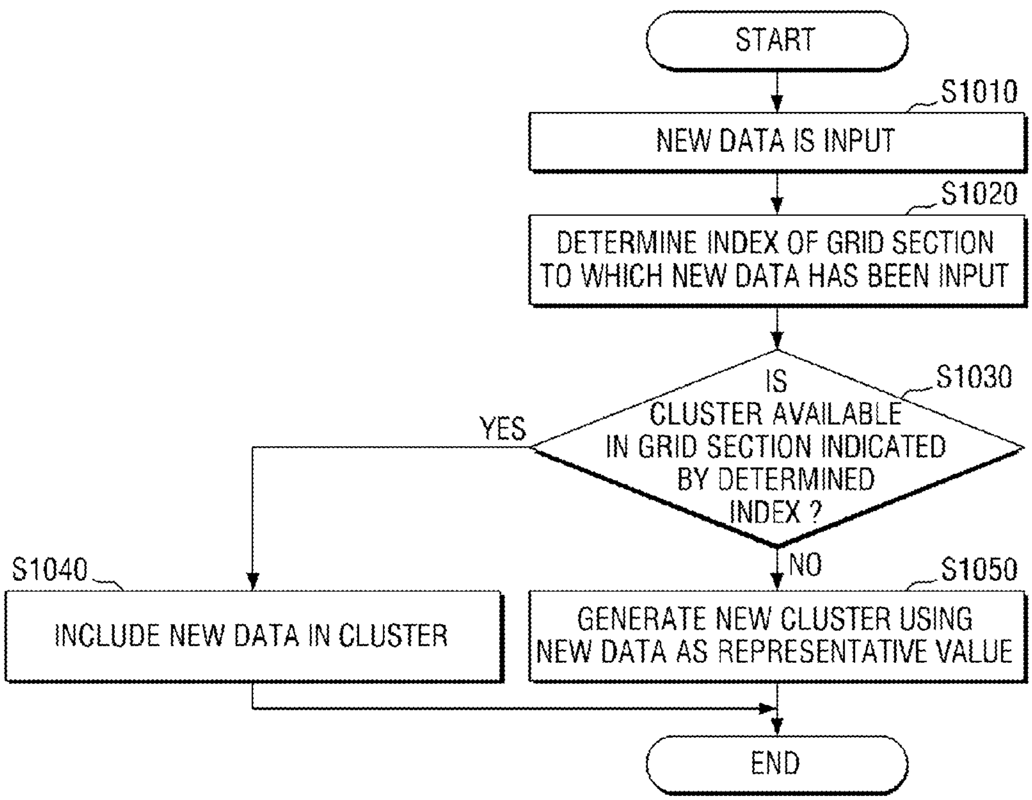

START
S910
RECEIVE TIME SERIES DATA FROM EACH SENSOR
S920
GENERATE ORDERED PAIR SET USING RECEIVED TIME SERIES DATA
S930
NORMALIZE VALUES OF EACH AXIS BY CALCULATING MEAN, VARIANCE AND STANDARD DEVIATION FOR EACH AXIS
S940
GENERATE GRID COORDINATE SYSTEM USING MINIMUM VALUE AND MAXIMUM VALUE AMONG NORMALIZED VALUES OF EACH AXIS AND SET DIFFERENT INDEX FOR EACH GRID SECTION OF GRID COORDINATE SYSTEM
S950
GENERATE A CLUSTER CORRESPONDING TO GRID SECTION, WHICH HAS ORDRED PAIRS, IN GRID COORDIANTE SYSTEM AND SET REPRESENTATIVE VALUE USING MEAN OF ORDERED PAIRS IN GENERATED CLUSTER
END

FIG 10


START
S1010
NEW DATA IS INPUT
S1020
DETERMINE INDEX OF GRID SECTION TO WHICH NEW DATA HAS BEEN INPUT
S1030
IS CLUSTER AVAILABLE IN GRID SECTION INDICATED BY DETERMINED INDEX ?
YES
NO
S1040
INCLUDE NEW DATA IN CLUSTER
S1050
GENERATE NEW CLUSTER USING NEW DATA AS REPRESENTATIVE VALUE
END

DATA ANALYSIS APPARATUS AND METHOD

This application claims priority from Korean Patent Application No. 10-2013-0062415 filed on May 31, 2013 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a heterogeneous data cluster generation apparatus and method and a data clustering method and apparatus, and more particularly, to a data clustering method and apparatus which cluster data measured by different sensors into a number of groups.

2. Description of the Related Art

A cluster is a group in which similar data among numerous data are gathered together, and clustering is to classify numerous data into a number of groups according to similarity.

In conventional cluster-based clustering methods such as K-means, K-medoids and canopy, when new data is input, distances between the new data and all clusters are calculated to find a cluster closest to the input data. Then, the new data is included in the found cluster. In the conventional clustering methods, however, the amount of calculation required significantly increases when the number of clusters increases as the size of data increases. If the number of clusters is reduced to overcome this problem, the data lose their original characteristic information, making it difficult to accurately identify the data.

Of the conventional clustering methods, a clustering method using a hierarchical algorithm such as K-D Tree does not require distance calculation for all clusters. However, if the number N of dimensions becomes greater than 10, the number of nodes to be searched in a space increases geometrically, thus slowing down calculation. In addition, since the hierarchical algorithm such as K-D Tree is not balanced, nodes should be rearranged periodically in order to strike a balance between the nodes.

Also, scattered data cannot be effectively clustered using the conventional clustering method. If the scattered data are clustered using the conventional clustering method, different clustering results may be produced every time. Therefore, if the scattered data are clustered using the conventional clustering method, re-clustering may be frequently performed during clustering, which, in turn, increases the amount of calculation required.

To reduce the amount of calculation, a technology of reducing the dimension of data may be used. In this case, however, the data may lose information, and outlier data of the reduced dimension cannot be identified. Thus, accurate clustering is difficult.

Furthermore, systems, such as a building energy management system (BEMS), which measure various data using numerous different types of sensors are increasing. However, a technology of generating clusters by putting together various data measured by numerous different types of sensors is not available, and a technology of rapidly and effectively clustering various data continuously measured by numerous different types of sensors is also not available. The absence of such technologies is because data measured by numerous different types of sensors in, e.g., the BEMS are massive and scattered data, and thus it is difficult to cluster the data rapidly and accurately. Accordingly, this has led to a demand for a technology of generating clusters by putting various heterogeneous data together and a technology of effectively clustering various newly input data.

SUMMARY OF THE INVENTION

Aspects of the present invention provide an apparatus and method for generating clusters by putting together heterogeneous data which are values measured by different types of sensors.

Aspects of the present invention also provide an apparatus and method for generating clusters by setting indices in order to effectively cluster multi-dimensional data, massive data, or scattered data.

Aspects of the present invention also provide an apparatus and method for rapidly and efficiently clustering newly input data by reducing the amount of calculation compared with a conventional clustering method by identifying a location of the newly input data using an index.

Aspects of the present invention also provide an apparatus and method more efficiently employed to cluster massive data.

Aspects of the present invention also provide an apparatus and method for effectively clustering scattered data, which cannot be effectively clustered using a conventional clustering method, by identifying a location of newly input data using an index.

However, aspects of the present invention are not restricted to the one set forth herein. The above and other aspects of the present invention will become more apparent to one of ordinary skill in the art to which the present invention pertains by referencing the detailed description of the present invention given below.

According to an aspect of the present invention, there is provided a heterogeneous cluster generation apparatus including: a reception unit receiving first time series data measured by a first sensor and second time series data measured by a second sensor which is a different type of sensor from the first sensor; a data merging unit generating an ordered pair set using the first time series data and the second time series data; and a cluster generation unit generating a cluster using the ordered pair set which corresponds to a location in a coordinate system composed of a first axis indicating measured values of the first time series data and a second axis indicating measured values of the second time series data, wherein the ordered pair set includes one or more ordered pairs, each composed of a measured value of the first time series data which corresponds to a specific time and a measured value of the second time series data which corresponds to the specific time.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects and features of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings, in which:

FIG. **1** is a block diagram of a heterogeneous data cluster generation apparatus according to an embodiment of the present invention;

FIGS. **2** through **5** are diagrams illustrating examples of generating ordered pairs using a data merging unit;

FIG. **6** is a block diagram of a cluster generation unit included in the heterogeneous data cluster generation apparatus of FIG. **1**;

FIG. **7** is a diagram illustrating an example of clusters generated by the cluster generation unit included in the heterogeneous data cluster generation apparatus of FIG. **1**;

FIG. **8** is a block diagram of a data clustering apparatus according to an embodiment of the present invention;

FIG. **9** is a flowchart illustrating a heterogeneous data cluster generation method according to an embodiment of the present invention; and

FIG. **10** is a flowchart illustrating a data clustering method according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Advantages and features of the present invention and methods of accomplishing the same may be understood more readily by reference to the following detailed description of exemplary embodiments and the accompanying drawings. The present invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the concept of the invention to those skilled in the art, and the present invention will only be defined by the appended claims. Like reference numerals refer to like elements throughout the specification.

It will be understood that when an element is referred to as being "connected to" or "coupled to" another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected to" or "directly coupled to" another element, there are no intervening elements present.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated components, steps, operations, and/or elements, but do not preclude the presence or addition of one or more other components, steps, operations, elements, and/or groups thereof.

A building energy management system (BEMS) is designed to manage the energy of a building. To manage the energy of a building, the BEMS collects various information from numerous different sensors such as a temperature measurement sensor, a humidity measurement sensor, a CO_2 concentration measurement sensor, a gas consumption measurement sensor, and a power consumption measurement sensor.

Therefore, measured values that the BEMS receives from sensors include numerous heterogeneous measured values. In addition, values measured even by the same type of sensors may exist over a wide spectrum depending on various measurement environments such as whether a sensor is installed outside or inside a building, whether the sensor operates at night or during the daytime, and whether the sensor is installed on the first floor or the twentieth floor of the building.

Recently, there has been, and continues to be, an increase in the diversity of a system for collecting large and various data using numerous heterogeneous sensors. That is, smart grid-related systems such as a facility management system (FMS) and a building automation system (BAS) have been introduced in addition to the BEMS.

A heterogeneous data cluster generation apparatus according to an embodiment of the present invention may generate clusters by putting together large and various data measured by numerous heterogeneous sensors. In addition, the heterogeneous data cluster generation apparatus according to the embodiment of the present invention can be used to effectively cluster multi-dimensional data, massive data, and scattered data.

The heterogeneous data cluster generation apparatus according to the embodiment of the present invention will now be described in detail with reference to FIGS. **1** through **7**.

FIG. **1** is a block diagram of a heterogeneous data cluster generation apparatus **100** according to an embodiment of the present invention.

Referring to FIG. **1**, the heterogeneous data cluster generation apparatus **100** according to the current embodiment may include a reception unit **110**, a data merging unit **120**, a normalization unit **130**, and a cluster generation unit **140**.

The reception unit **110** receives time series data from each of a first sensor **10** and a second sensor **20** which are heterogeneous sensors. Specifically, the reception unit **110** receives from the first sensor **10** and the second sensor **20** data about values measured in a time series manner by the first sensor **10** and the second sensor **20** (for measuring heterogeneous information), together with information about times when the values were measured.

That is, the reception unit **110** may receive first time series data measured by the first sensor **10** and second time series data measured by the second sensor **20**.

The term "time series data", as used herein, denotes data measured periodically or non-periodically over time.

Although two different sensors are described as an example to help understand the present invention, more than thousands of sensors (a third sensor, a fourth sensor, etc.) can be used.

The first sensor **10** and the second sensor **20** may measure different types of information. The first sensor **10** and the second sensor **20** may be, for example, a temperature measurement sensor and a power consumption measurement sensor, respectively.

If there are three or more sensors, at least one of the sensors should be a sensor that measures a different type of information from the other sensors. However, the other sensors can be sensors that measure the same type of information. Although the other sensors are sensors that measure the same type of information, they may produce significantly different measured values depending on their measurement environments. For example, both the second sensor **20** and a third sensor may be located on the first floor of a building, or the second sensor **20** may be located on the first floor while the third sensor is located on the rooftop.

That is, measured value data received by the reception unit **110** of the heterogeneous data cluster generation apparatus **100** according to the current embodiment are not all the same type of information but include heterogeneous information measured by heterogeneous sensors. Here, the heterogeneous information denotes measured values having different meanings or units.

The reception unit **110** is connected to each sensor in a wired or wireless manner so as to receive a measured value from each sensor in real time, periodically, or non-periodically.

The data merging unit **120** generates an ordered pair set using the first time series data and the second time series data received by the reception unit **110**. The ordered pair set generated by the data merging unit **120** includes one or more ordered pairs, each composed of a measured value of the first time series data which corresponds to a specific time and a measured value of the second time series data which corresponds to the specific time.

The cluster generation unit **140** may generate a cluster using the ordered pair set which corresponds to a location in a coordinate system composed of a first axis and a second axis.

An ordered pair generated by the data merging unit **120** may be (a value of the first axis, a value of the second axis) corresponding to a specific time.

The first axis represents measured values of the first time series data, and the second axis represents measured values of the second time series data. Therefore, the number of axes may be set differently according to the number of sensors, the number of types of sensors, and the type of data measured by each sensor. For example, the reception unit **110** may receive measured value data from the first sensor **10** which measures temperature on the second floor of a building, the second sensor **20** which measures humidity on the second floor of the building, and the third sensor which measures water consumption on the second floor of the building. In this case, the number of axes may be determined to be three based on the three types of sensors that measure different information.

The coordinate system may be a plane or a space. That is, a coordinate system composed of two axes may be a plane, and a coordinate system composed of three axes may be a space.

The cluster generation unit **140** will be described in greater detail later after the data merging unit **120**.

When the data merging unit **120** generates an ordered pair set, the difference in measurement time of each sensor can be a problem.

To generate an ordered pair set, the data merging unit **120** may use a measured value of the first time series data which corresponds to a specific time and a measured value of the second time series data which corresponds to the specific time. Here, the time corresponding to the specific time may be the same time as the specific time.

Alternatively, the time corresponding to the specific time may be within a preset time range ThT_{ime} from the specific time. For example, if the specific time is 3.5 seconds and if the preset time range ThT_{ime} is 0.5 seconds, the time corresponding to the specific time may be in a range of 3 to 4 seconds. That is, the value of the second axis set by the data merging unit **120** may be a value measured by the second sensor **20** between 3 and 4 seconds.

Alternatively, if measured value data received by the reception unit **110** does not include a value measured by the second sensor **20** at the same time as the specific time, a time closest to the specific time among measurement times of the second sensor **20** before the specific time may be set as the time corresponding to the specific time.

Alternatively, if the measured value data received by the reception unit **110** does not include a value measured by the second sensor **20** at the same time as the specific time, a time closest to the specific time among measurement times of the second sensor **20** before and after the specific time may be set as the time corresponding to the specific time.

The specific time may be the same as a measurement time of the first sensor **10** or a measurement time of the second sensor **20**. Alternatively, the specific time may have a different interval from a measurement interval of the first sensor **10** and a measurement interval of the second sensor **20**.

The time corresponding to the specific time may be set differently from the above description according to a user's intention or the degree of information collection by each sensor. However, the data merging unit **120** may construct an ordered pair set using time series data measured at similar times by the first sensor **10** and the second sensor **20**.

Examples of generating ordered pairs using the data merging unit **120** will now be described in detail with reference to FIGS. **2** through **5**.

FIGS. **2** through **5** are diagrams illustrating examples of generating ordered pairs using the data merging unit **120**.

Referring to FIG. **2**, the first sensor **10** measures information at intervals of T_1, and the second sensor **20** also measures information at intervals of T_1. Assuming that the first sensor **10** and the second sensor **20** start to measure information from 0 seconds and that T_1 is 2 seconds, time series data of the first sensor **10** received by the reception unit **110** and represented in the form of (a measured value, a measurement time) may be (a,0), (b,2), (c,4), (d,6), (e,8), (f,10), and (g,12). Likewise, time series data of the second sensor **20** received by the reception unit **110** and represented in the form of (a measured value, a measurement time) may be (ㄱ,0), (ㄴ,2), (ㄷ,4), (ㄹ,6), (ㅁ,8), (ㅂ,10), and (ㅅ,12).

The data merging unit **120** may set a value 'a' measured by the first sensor **10** at a specific time of 0 seconds as the value of the first axis and a value 'ㄱ' measured by the second sensor **20** at the same time (0 seconds) as the specific time of 0 seconds as the value of the second axis. In addition, the data merging unit **120** may set a value 'b' measured by the first sensor **10** at another specific time of 2 seconds as the value of the first axis and a value 'ㄴ' measured by the second sensor **20** at the same time (2 seconds) as the another specific time as the value of the second axis. By applying this setting process to data of up to 12 seconds received by the reception unit **110**, the data merging unit **120** may generate an ordered pair set of (a,ㄱ), (b,ㄴ), (c,ㄷ), (d,ㄹ), (e,ㅁ), (f,ㅂ), and (g,ㅅ). Specifically, (a,ㄱ) is an ordered pair generated by the data merging unit **120** using 'a' as the value of the first axis and 'ㄱ' as the value of the second axis at a specific time of 0 seconds. In addition, (b,ㄴ) is an ordered pair generated by the data merging unit **120** using 'b' as the value of the first axis and 'ㄴ' as the value of the second axis at another specific time of 2 seconds. In addition, (c,ㄷ) is an ordered pair generated by the data merging unit **120** using 'c' as the value of the first axis and 'ㄷ' as the value of the second axis at another specific time of 4 seconds. For each specific time when a measured value of the first sensor **10** exists, a value measured by the second sensor **20** at a time corresponding to the specific time may be generated as the value of the second axis. However, the specific time is not necessarily a time when the measured value of the first sensor **10** exists. Each time arriving at specific intervals T_0 may also be set as the specific time. This will be described later using an example with reference to FIG. **4**.

An example of generating an ordered pair set using the data merging unit **120** in a case where the measurement interval of the first sensor **10** and the measurement interval of the second sensor **20** are different will now be described with reference to FIG. **3**.

In FIG. **3**, a measurement interval T_1 of the first sensor **10** is longer than a measurement interval T_2 of the second sensor **20**. That is, in FIG. **3**, not all values measured by the first sensor **10** and the second sensor **20** are values measured at the same time. Thus, the data merging unit **120** may generate an ordered pair by setting a time closest to a specific time among measurement times of the second sensor **20** before the specific time as a time corresponding to the specific time.

For example, assuming that the measurement interval T_1 of the first sensor **10** is 2 seconds in FIG. **3**, the time series data of the first sensor **10** may be (a,0), (b,2), (c,4), (d,6), (e,8), and (f,10). In addition, assuming that the measurement interval T_2 of the second sensor **20** is 1.2 seconds, the time series data of the second sensor **20** may be (ㄱ,0), (ㄴ,1.2), (ㄷ,2.4), (ㄹ,3.6), (ㅁ,4.8), (ㅂ,6), (ㅅ,7.2), (ㅇ,8.4), (ㅈ,9.6), and (ㅊ,10.8).

In the case of FIG. **3**, the data merging unit **120** may generate (a, ㄱ), (b,ㄴ), (c,ㄹ), (d,ㅂ), (e, ㅅ), and (f,ㅈ) as an ordered pair set.

Even when the measurement interval of the first sensor **10** is shorter than that of the second sensor **20**, the data merging unit **120** may generate an ordered pair set as described above with reference to FIG. **3**.

Specifically, in FIG. **3**, the data merging unit **120** may generate an ordered pair set by setting a value measured by the second sensor **20** as the value of the first axis and setting a value measured by the first sensor **10** as the value of the second axis. In this case, the ordered pair set generated by the data merging unit **120** may be (ㄱ,a), (ㄴ,a), (ㄷ,b), (ㄹ,b), (ㅁ,c), (ㅂ,d), (ㅅ,d), (ㅇ,e), (ㅈ,e), and (ㅊ,f).

The data merging unit **120** may also not generate an ordered pair set by setting a time when data measured by the first sensor **10** or the second sensor **20** exists as a specific time. That is, the data merging unit **120** may generate an ordered pair set at the specific intervals T_0. If the data merging unit **120** generates an ordered pair set by setting each time arriving at the specific intervals T_0 as the specific time, an ordered pair set may be generated using a time closest to the specific time arriving among measurement value of each sensor existing before the specific time of the specific intervals T_0.

That is, if the specific time is set to a time arriving at the specific intervals T_0, the data merging unit **120** may regard a value measured at a time closest to the specific time among values measured by the first sensor **10** at times before the specific time as a value measured by the first sensor **10** at the specific time and set the value measured at the time closest to the specific time as the value of the first axis. In addition, the data merging unit **120** may regard a time closest to the specific time among measurement times of the second sensor **20** before the specific time as a time corresponding to the specific time and set a value measured by the second sensor **20** at the time corresponding to the specific time as the value of the second axis.

For example, in the case of FIG. **4**, a measured value of the first sensor **10** and a measured value of the second sensor **20** received by the reception unit **110** may be as illustrated in FIG. **3**, and the data merging unit **120** may set the specific interval T_0 to 0.8 seconds.

Referring to FIG. **4**, at a first specific time of 0 seconds, the value of the first axis is 'a,' and the value of the second axis is 'ㄱ.' At a second specific time of 0.5 seconds after the specific interval T_0, the value of the first axis is 'a,' and the value of the second axis is 'ㄱ.' At a third specific time of 1 second after the specific interval T_0, the value of the first axis is 'a,' and the value of the second axis is 'ㄱ.' At a fourth specific time of 1.5 seconds after the specific interval T_0, the value of the first axis is 'a,' and the value of the second axis is 'ㄴ' measured at a time of 1.2 seconds. An ordered pair set generated by the data merging unit **120** in this way in FIG. **4** may be (a,ㄱ), (a,ㄱ), (a,ㅣ-), (b,ㄷ), (b,ㄷ), (c,ㄹ), (c,ㅁ), (c,ㅁ), (d,ㅂ), (d,ㅅ), (e,ㅅ), (e,ㅇ), (e,ㅈ), (f,ㅈ), and (f,ㅊ).

As described above using examples with reference to FIGS. **3** and **4**, when measured value data received by the reception unit **110** does not include a value measured by the second sensor **20** at the same time as a specific time, the data merging unit **120** may set a time closest to the specific time among measurement times of the second sensor **20** before the specific time as a time corresponding to the specific time.

As described above, when the measured value data received by the reception unit **110** does not include a value measured by the second sensor **20** at the same time as the specific time, the data merging unit **120** may also set a time closest to the specific time among measurement times of the second sensor **20** before and after the specific time as the time corresponding to the specific time. A case where the data merging unit **120** generates an ordered pair set in view of values existing not only before but also after the specific time will now be described using an example with reference to FIG. **5**.

Referring to FIG. **5**, a measured value of the first sensor **10**, a measured value of the second sensor **20**, T_1 and T_2 received by the reception unit **110** are as illustrated in FIG. **3**.

In FIG. **5**, since T_1 is 2 seconds and T_2 is 1.2 seconds, 2.4 seconds is closer to a specific time of 2 seconds among 1.2 and 2.4 seconds when the second sensor **20** measured values. Therefore, the data merging unit **120** may set a value 'b' measured by the first sensor **10** at the specific time of 2 seconds as the value of the first axis and a value 'ㄷ' measured by the second sensor **20** at a time of 2.4 seconds corresponding to the specific time of 2 seconds as the value of the second axis. An ordered pair set generated by the data merging unit **120** in this way in FIG. **5** may be (a,ㄱ), (b,ㄷ), (c,ㄹ), (d,ㅂ), (e,ㅇ), and (f,ㅈ).

To generate an ordered pair set in the same way as the data merging unit **120** did in FIG. **5**, the reception unit **110** may receive measured value data of each sensor and generate an ordered pair set after a predetermined period of time in view of the measurement interval of each sensor.

In addition, the method of generating an ordered pair set using the data merging unit **120** in view of values existing not only before a specific time but also after the specific time can be applied to the method of generating an ordered pair set using the specific interval T_0 described above with reference to FIG. **4**.

When the measurement start time of each sensor is different, the data merging unit **120** may also generate an ordered pair set using the method described above with reference to FIGS. **3** through **5** for a case where the measurement interval of the first sensor **10** and the measurement interval of the second sensor **20** are different.

When time series data of a third sensor exists, the data merging unit **120** may set the time series data of the third sensor as a value of a third axis. When time series data of a fourth sensor exists, the data merging unit **120** may set the time series data of the fourth sensor as a value of a fourth axis. In this case, an ordered pair generated by the data merging unit **120** may be in the form of (the value of the first axis, the value of the second axis, the value of the third axis, the value of the fourth axis).

FIG. **6** is a block diagram of the cluster generation unit **140** included in the heterogeneous data cluster generation apparatus **100** of FIG. **1**.

Referring to FIG. **6**, the cluster generation unit **140** may include an index setting unit **142** and a representative value setting unit **144**.

The index setting unit **142** may set a minimum value and a maximum value of the time series data of the first sensor **10** as a minimum value and a maximum value of the first axis and set a minimum value and a maximum value of the time series data of the second sensor **20** as a minimum value and a maximum value of the second axis.

In addition, the index setting unit **142** may generate a grid coordinate system by dividing a coordinate system (which is a plane when having two axes and is a space when having three axes) having a first axis and a second axis into a plurality of grid sections according to preset sensitivity and set a different index for each grid section. The coordinate system may be divided into the grid sections of equal sizes according to the preset sensitivity. When there are three or more axes, the index setting unit **142** may divide a space formed by the three or more axes into a plurality of grid spaces of equal sizes and set a different index for each grid space. In the present invention, since the coordinate system composed of the first axis and the second axis is described as an example, the term “grid section” is used. However, the present invention is not limited thereto. When there are three or more axes, grid spaces may be used without departing from the scope of the present invention.

The preset sensitivity may vary according to a user’s setting, the system environment, the type of sensor, the amount of data, etc. The preset sensitivity is a parameter that can adjust the size of a cluster.

The data merging unit **120** may input a generated ordered pair set to a corresponding one of the grid sections generated by the index setting unit **142**. The representative value setting unit **144** may generate clusters in grid sections having input data (ordered pairs) among the generated grid sections and set a representative value of each cluster.

When a plurality of data exist in one cluster, the representative value setting unit **144** may set the mean of the data as a representative value of the cluster or may set the representative value of the cluster using a preset method other than the mean.

Referring back to FIG. **1**, the heterogeneous data cluster generation apparatus **100** according to the current embodiment may include the normalization unit **130**.

The normalization unit **130** may perform normalization for each axis in order to generate clusters through reasonable intersection of axes.

If the normalization unit **130** does not perform normalization on each axis, the proportion of clusters generated by the cluster generation unit **140** may be greatly different for each axis due to the difference in the measured value of each sensor. Accordingly, ordered pair sets composed of measured values of the sensors may not be efficiently distributed. The normalization unit **130** may also increase easiness in comparing measured values in different the mean and unit.

The normalization unit **130** may calculate the mean and variance of the first time series data and the mean and variance of the second time series data, normalize the first time series data using the calculated mean and variance of the first time series data, and normalize the second time series data using the calculated mean and variance of the second time series data.

After the normalization by the normalization unit **130**, the data merging unit **120** may generate an ordered pair set using the normalized first time series data and the normalized second time series data. Here, the generated ordered pair set may include one or more normalized ordered pairs, each composed of a value obtained by normalizing a measured value of the first time series data which corresponds to a specific time and a value obtained by normalizing a measured value of the second time series data which corresponds to the specific time. Alternatively, the normalization unit **130** may normalize an ordered pair set generated by the data merging unit **120** and generate the normalized ordered pair set.

After the normalization by the normalization unit **130**, the index setting unit **142** may set a minimum value and a maximum value of the normalized first time series data as the minimum value and the maximum value of the first axis and set a minimum value and a maximum value of the normalized second time series data as the minimum value and the maximum value of the second axis. Then, the index setting unit **142** may divide a section composed of the first axis and the second axis into the grid sections according to the preset sensitivity and set a different index for each grid section.

After the normalization by the normalization unit **130**, the cluster generation unit **140** may generate a cluster using the ordered pair set which corresponds to a location in the section composed of the first axis indicating measured values of the normalized first time series data and the second axis indicating measured values of the normalized second time series data.

Specifically, the normalization unit **130** may calculate the mean and variance using measured values of time series data and perform normalization using the calculated mean and variance. More specifically, the normalization unit **130** may perform normalization such as Z-score normalization by using the mean and variance calculated for each axis and a standard deviation calculated from the variance. A Z-score is one of standard scores and one of transformed scores obtained by dividing deviation scores from the mean by a standard deviation of the distribution of the deviation scores. Specifically, the Z-score may be calculated using Equation (1):

$$Z=(X-X')/S, \tag{1}$$

where Z is a transformed score obtained by Z-score normalization, X is a value of each axis, X' is the mean of values of each axis, and S is a standard deviation of the values of each axis.

Referring back to FIG. **6**, if the normalization unit **130** performs normalization on each axis, the index setting unit **142** may set a minimum value and a maximum value among normalized values (values indicated by the normalized first time series data) of the first axis as the minimum value and the maximum value of the first axis and set a minimum value and a maximum value among normalized values (values indicated by the normalized second time series data) of the second axis as the minimum value and the maximum value of the second axis.

In addition, the index setting unit **142** may generate the grid sections by dividing the first axis and the second axis according to the preset sensitivity and set a different index for each grid section. To change the size of each cluster, the preset sensitivity may be changed.

The representative value setting unit **144** may generate a cluster in each grid section having ordered pairs. In addition, the representative value setting unit **144** may set a representative value of the generated cluster by using normalized ordered pairs existing in the generated cluster. A representative value of each cluster set by the representative value setting unit **144** may be the mean of ordered pairs existing in the cluster.

An example of clusters generated by the cluster generation unit **140** will now be described with reference to FIG. **7**.

In FIG. **7**, the index setting unit **142** may generate 100×100 grid sections. Accordingly, 10,000 indices ranging from (1,1) to (100,100) may be set for the grid sections, respectively. A cluster having an index of (2,2) may include $Data_1$ and $Data_2$ as ordered pairs. Thus, the representative value setting unit **144** may set the mean of $Data_1$ and $Data_2$ as a representative value RV_2. A cluster having an index of (4,3) may include $Data_3$ as an ordered pair. Thus, the representative value setting unit **144** may set a value of $Data_3$ as a representative value. In FIG. **7**, dots indicate ordered pair sets generated by the data merging unit **120** and input to corresponding grid sections. RV_1 through RV_7 indicate representative values of clusters, respectively, and numbers from 1 to 100 on each axis indicate index information.

The heterogeneous data cluster generation apparatus **100** according to the present invention may generate clusters by putting together heterogeneous data measured by different sensors.

In conventional clustering methods such as K-means, K-medoids, canopy and a hierarchical algorithm, when new data is input, distances between the new data and all clusters are calculated to find a cluster closest to the input data. Then, the new data is clustered in the found cluster. Therefore, in the conventional clustering methods, the amount of calculation required significantly increases if massive data exist in the clusters, and scattered data are not clustered efficiently. However, a data clustering apparatus according to an embodiment of the present invention can reduce the amount of calculation required for clustering and efficiently cluster scattered data by using clusters with set indices and arranged in a grid structure.

FIG. **8** is a block diagram of a data clustering apparatus **800** according to an embodiment of the present invention.

The data clustering apparatus **800** according to the current embodiment will now be described with reference to FIG. **8**. Referring to FIG. **8**, the data clustering apparatus **800** according to the current embodiment includes a reception unit **110**, a data merging unit **120**, a normalization unit **130**, a cluster generation unit **140**, an index determination unit **810**, and a clustering unit **820**.

That is, when new data is input to a cluster generated by the heterogeneous data cluster generation apparatus **100** according to the embodiment of FIG. **1**, the data clustering apparatus **800** according to the current embodiment clusters the new data. Therefore, the reception unit **110**, the data merging unit **120**, the normalization unit **130** and the cluster generation unit **140** described above with reference to FIGS. **1** through **7** will not be described in detail here, and only the index determination unit **810** and the clustering unit **820** will be described in detail.

When new data (a new ordered pair) is input to a generated cluster, the index determination unit **810** determines an index of a grid section to which the new data has been input. The new data may be data obtained by normalizing an ordered pair generated by the data merging unit **120** using the normalization unit **130**.

Specifically, the data merging unit **120** may generate an ordered pair using a new measured value received by the reception unit **110** from each sensor, and the normalization unit **130** may normalize the generated ordered pair. The normalized ordered pair may be the new data

The index determination unit **810** may determine an index of a grid section in which newly input data exists by using Equations (2) and (3):

$$z' = \frac{x' - E[X]}{\sigma[X]}, \tag{2}$$

In Equation (2), newly input data is normalized using Z-score normalization. In Equation (2), z' is a value obtained by normalizing new data, x' is newly input data, E[x] is the mean of ordered pairs stored in a cluster, and σ[x] is a standard deviation of the ordered pairs stored in the cluster. If z is an ordered pair composed of the value of the first axis and the value of the second axis, a normalized ordered pair z' is calculated by normalizing the value of the first axis and the value of the second axis using Equation (2). Calculating a normalized ordered pair of newly input data using Equation (2) may also be performed by the normalization unit **130**.

An index of a grid section to which new data has been input may be determined using Equation (3) and the normalized ordered pair z' calculated using Equations (2):

$$\text{Index} = \text{ceiling}\left[\frac{(z' - \min[z])}{\max[z] - \min[z]} \times \frac{1}{grpNum}\right], \tag{3}$$

where Index is an index of normalized new data, z' is a normalized value of newly input data, min[z] is a minimum value among values of each axis stored in a cluster, max[z] is a maximum value among the values of each axis stored in the cluster, grpNum is the number of indices of each axis, and ceiling is a ceiling function.

The index determination unit **810** may determine index information of an ordered pair by applying Equation (3) to each normalized value of each axis that forms the normalized ordered pair z'.

When the index determination unit **810** determines an index of newly input ordered pair data, the clustering unit **820** determines a cluster of the newly input data using the determined index.

Specifically, when the index determination unit **810** determines an index, the clustering unit **820** may determine whether a cluster is available in a section indicated by the determined index and obtain representative value information of the cluster if the cluster is available.

When no cluster is available in the section indicated by the determined index, the clustering unit **820** may generate a new cluster by using ordered pair data newly input to the section indicated by the determined index as a representative value.

In addition, when a cluster is available in the section indicated by the determined index, the clustering unit **820** may include the newly input ordered pair data in the cluster and change a representative value of the cluster using the newly input ordered pair data.

The clustering unit **820** may also identify a representative value existing closest to a location to which the new ordered pair data has been input by calculating distances between representative values existing in sections, which correspond to indices, around the location of the newly input ordered pair data.

FIG. **9** is a flowchart illustrating a heterogeneous data cluster generation method according to an embodiment of the present invention.

Referring to FIG. **9**, in the heterogeneous data cluster generation method according to the current embodiment, the reception unit **110** may receive first time series data measured by a first sensor and second time series data measured by a second sensor which is a different type of sensor from the first sensor (operation S**910**).

The data merging unit **120** may generate an ordered pair set using the first time series data and the second time series data (operation S**920**). The ordered pair set generated by the data merging unit **120** may include one or more ordered pairs, each composed of a measured value of the first time series data which corresponds to a specific time and a measured value of the second time series data which corresponds to the specific time.

The normalization unit **130** may calculate the mean and variance of the first time series data and the mean and variance of the second time series data, normalize the first time series data using the calculated mean and variance of the first time series data, and normalize the second time series data using the calculated mean and variance of the second time series data (operation S**930**).

The ordered pair set generated by the data merging unit **120** may use the normalized first time series data and the normalized second time series data, and the normalization unit **130** may generate a normalized ordered pair set by normalizing the ordered pair set generated by the data merging unit **120**.

The index setting unit **142** may set a minimum value and a maximum value of the normalized first time series data as a minimum value and a maximum value of a first axis and a minimum value and a maximum value of the normalized second time series data as a minimum value and a maximum value of a second axis, generate a grid coordinate system by dividing a coordinate system composed of the first axis and the second axis into a plurality of grid sections according to preset sensitivity, and set a different index for each grid section (operation S**940**).

The representative value setting unit **144** may generate a cluster using the normalized ordered pair set which corresponds to a location in the coordinate system composed of the first axis indicating measured values of the normalized first time series data and the second axis indicating measured values of the normalized second time series data and set a representative value of the generated cluster using normalized ordered pairs existing in the generated cluster (operation S**950**).

FIG. **10** is a flowchart illustrating a data clustering method according to an embodiment of the present invention.

Referring to FIG. **10**, in the data clustering method according to the current embodiment, when new data is input to any one of grid sections generated using the heterogeneous data cluster generation method according to the embodiment of FIG. **9** (operation S**1010**), the index determination unit **810** may determine an index of the grid section to which the new data has been input (operation S**1020**). The grid sections may be sections into which a section composed of two axes, i.e., a first axis and a second axis is divided. However, the present invention is not limited thereto, and the grid sections may also be understood as sections into which a space formed by three or more axes is divided. The new data may be data generated as an ordered pair by the data merging unit **120** using a value received by the reception unit **100** from each sensor. The new data may also be an ordered pair normalized by the normalization unit **130**.

When a cluster is available in the grid section indicated by the determined index, the clustering unit **820** may include the newly input ordered pair data in the cluster and change a representative value of the cluster using the newly input ordered pair data (operations S**1020** and S**1040**).

When no cluster is available in the grid section indicated by the determined index, the clustering unit **820** may generate a new cluster by using the ordered pair data newly input to the grid section indicated by the determined index as a representative value (operations S**1030** and S**1050**).

The clustering unit **820** may also identify a representative value existing closest to a location to which the new ordered pair data has been input by calculating distances between representative values existing in sections, which correspond to indices, around the location of the newly input ordered pair data.

Each component described above with reference to FIGS. **1**, **6** and **8** may be implemented as a software component or a hardware component such as a Field Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC). Each component is not limited to the software or hardware component and may advantageously be configured to reside on the addressable storage medium and configured to execute on one or more processors. The functionality provided for in the components may be further separated into additional components or combined into fewer components.

A heterogeneous data cluster generation apparatus and method according to the present invention can generate clusters by putting together heterogeneous data measured by different sensors.

The heterogeneous data cluster generation apparatus and method according to the present invention can also generate clusters used to effectively cluster multi-dimensional data, massive data, or scattered data.

A data clustering method and apparatus according to the present invention can reduce the amount of calculation required for clustering, compared with a conventional clustering method.

The data clustering method and apparatus according to the present invention can also cluster massive data rapidly and accurately, compared with the conventional clustering method.

The data clustering method and apparatus according to the present invention can rapidly and accurately cluster scattered data which cannot be easily clustered using the conventional clustering method.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the present invention as defined by the following claims. The exemplary embodiments should be considered in a descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A data analysis apparatus comprising:

a receiver configured to receive first time series data measured by a first sensor and second time series data measured by a second sensor;

a data merging unit configured to generate an ordered pair set using the first time series data and the second time series data; and

a cluster generation unit configured to generate a cluster, using the ordered pair set, the cluster being generated in accordance with one or more locations in a coordinate system having a first axis indicating measured values of the first time series data and a second axis indicating measured values of the second time series data,

wherein the ordered pair set comprises one or more ordered pairs, each including a measured value of the first time series data corresponding to a specific time, and a measured value of the second time series data corresponding to the specific time.

2. The apparatus of claim **1**, wherein the second sensor is configured to measure a unit of data different from a unit of data measured by the first sensor.

3. The apparatus of claim **1**, wherein the cluster generation unit comprises an index setting unit configured to: set a minimum value and a maximum value of the first time series data, as a minimum value and a maximum value of the first axis; set a minimum value and a maximum value, of the second time series data, as a minimum value and a maximum value of the second axis; generate a grid coordinate system by dividing the coordinate system into grid sections according to a preset sensitivity level, and set a different index for each of the grid sections.

4. The apparatus of claim **1**, further comprising:

a normalization unit configured: to calculate the mean and variance of the first time series data and the mean and variance of the second time series data; to normalize the first time series data using the calculated mean and variance of the first time series data to provide normalized first time series data; and to normalize the second time series data using the calculated mean and variance of the second time series data to provide normalized second time series data; and

an index setting unit configured to: set a minimum value and a maximum value, of the normalized first time series data, as the minimum value and the maximum value of the first axis; set a minimum value and a maximum value, of the normalized second time series data, as the minimum value and the maximum value of the second axis; generate the grid coordinate system by dividing the coordinate system into grid sections according to a preset sensitivity level; and set a different index for each of the grid sections.

5. The apparatus of claim **4**, wherein:

the data merging unit is further configured to generate a normalized ordered pair set using the normalized first time series data and the normalized second time series data;

the cluster generation unit is further configured to generate a normalized cluster, using the normalized ordered pair set, the normalized cluster being generated in accordance with one or more locations in the coordinate system with the first axis indicating measured values of the normalized first time series data and the second axis indicating measured values of the normalized second time series data,

wherein the normalized ordered pair set comprises one or more normalized ordered pairs, each including a value of the normalized first time series data which corresponds to the specific time, and a value of the normalized second time series data which corresponds to the specific time.

6. The apparatus of claim **5**, wherein the cluster generation unit comprises a representative value setting unit configured to generate a region having the normalized ordered pairs corresponding to the location in the grid coordinate system as the normalized cluster, and to set a representative value, of the normalized cluster, using the normalized ordered pairs existing in the generated cluster.

7. The apparatus of claim **6**, wherein the representative value setting unit is further configured to set the normalized ordered pair as the representative value when the cluster comprises only one normalized ordered pair, and to seta mean of the two or more normalized ordered pairs as the representative value when the cluster comprises two or more normalized ordered pairs.

8. The apparatus of claim **1**, wherein:

the measured value corresponding to the specific time is data measured at the specific time among the time series data received by the receiver, and

when the data measured does not exist for the specific time, the measured value corresponding to the specific time is taken as a value measured at a preceding time closest to the specific time, among the measured time series data.

9. The apparatus of claim **1**, wherein:

the measured value corresponding to the specific time is data measured at the specific time among the time series data received by the receiver, and

when the data measured does not exist for the specific time, the measured value corresponding to the specific time is taken as a value measured at a time closest to the specific time, among the time series data.

10. The apparatus of claim **1**, wherein the specific time is based on at least one of: a measurement time of the first sensor, a measurement time of the second sensor, and a time arriving at specific intervals.

11. The apparatus of claim **1**, wherein:

the receiver is further configured to receive third time series data measured by a third sensor, and

the data merging unit is further configured to generate each of the one or more ordered pairs so as to include a measured value of the third time series data corresponding to the specific time.

12. A data analysis method comprising:

receiving first time series data measured by a first sensor and second time series data measured by a second sensor;

generating an ordered pair set using the first time series data and the second time series data; and

generating a cluster, using the ordered pair set, the cluster being generated in accordance with one or more locations in a coordinate system having a first axis indicating measured values of the first time series data and a second axis indicating measured values of the second time series data,

wherein the ordered pair set comprises one or more ordered pairs, each including a measured value of the first time series data corresponding to a specific time, and a measured value of the second time series data corresponding to the specific time;

wherein at least one of the receiving, the generating of the ordered pair set, and the generating of the cluster is implemented using one or more hardware processors.

13. The method of claim **12**, further comprising:

measuring the data with the second sensor using a unit of data different from a unit of data measured by the first sensor.

14. The method of claim **12**, further comprising:

calculating the mean and variance of the first time series data and the mean and variance of the second time series data;

normalizing the first time series data using the calculated mean and variance of the first time series data to provide normalized first time series data;

normalizing the second time series data using the calculated mean and variance of the second time series data to provide normalized second time series data;

setting a minimum value and a maximum value of the normalized first time series data as a minimum value and a maximum value of the first axis;

setting a minimum value and a maximum value of the normalized second time series data as a minimum value and a maximum value of the second axis;

generating a grid coordinate system by dividing a coordinate system into grid sections according to a preset sensitivity level; and

setting a different index for each of the grid sections.

* * * * *